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Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 to nuclear fuel resources

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Bridging Document between the Organisation of Economic Co-operation and Development Nuclear Energy Agency/International Atomic Energy Agency Uranium Classification and UNFC-2009

Final draft prepared by the Task Force on Application of UNFC-2009 to Nuclear Fuel Resources[1]

I. Introduction

1. Bridging documents explain the relationship between the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) and another classification system that has been endorsed by the Expert Group on Resource Classification as an Aligned System. They incorporate instructions and guidelines on how to classify estimates generated by application of that Aligned System using the UNFC-2009 Numerical Codes. The relevant bridging document shall be identified when reporting estimates using the UNFC-2009 Numerical Codes.

[1] Please note that this final draft Bridging Document was prepared by the Task Force on the Application of UNFC-2009 to Nuclear Fuel Resources of the Expert Group on Resource Classification following careful consideration of all comments received from stakeholders. This document is submitted to the Expert Group on Resource Classification at its fifth session for endorsement.

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2. Two international systems have been used for classification and reporting of uranium and thorium deposits. These include the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template and the Organisation of Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA)/International Atomic Energy Agency (IAEA) resource reporting scheme. Exploration Results, Mineral Resources and Mineral Reserves for uranium and thorium deposits prepared under the CRIRSCO family of aligned codes and standards, can be mapped to the UNFC-2009 Numerical Codes by applying the Bridging Document between the CRIRSCO Template and UNFC-2009[2].

3. UNFC-2009 is a project-based system that applies to all fossil energy and mineral reserves and resources. It has been designed to meet, to the extent possible, the needs of applications pertaining to energy and mineral studies, resource management functions, corporate business process and financial reporting standards. The NEA/IAEA scheme was developed for reporting individual, regional, national and international uranium resource estimates. As discussed below, the scheme has also been used to classify thorium resources.

4. The purpose of this Bridging Document is to facilitate the mapping of results between UNFC-2009 and the NEA/IAEA resources reporting scheme. The mapping of NEA/IAEA results for individual deposits into UNFC-2009 requires the application of "Production Terminology" as defined in Section II.B of this Bridging Document, the instructions set out in Section III of this Bridging Document, the commodity-specific specifications compiled in the CRIRSCO Template[3], and the Generic Specifications for the application of UNFC-2009 (ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Section VI).

5. Along with the UNFC-2009 Generic Specifications, these instructions and guidelines provide the foundation and keystones for consistent application of UNFC-2009 for the reporting of uranium and thorium[4] resources.

6. Unless constrained by regulation, the application of the instructions and guidelines in this Bridging Document shall not limit in any way the use of the full granularity provided in UNFC-2009.

II. Overview of NEA/IAEA classification scheme

A. Overview

7. In the mid-1960s, NEA and IAEA began the publication of a report entitled: "Uranium – Resources, Production and Demand". The report, commonly known as the "Red Book", has been published at roughly two-year intervals; the 2011 edition is the twenty-fourth edition. The report has become widely recognized in the international nuclear

[2] ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Annex III.

[3] Refer to the fifth paragraph of Section B "Detailed mapping of the E and F axes" of the Bridging Document between the CRIRSCO Template and UNFC-2009, ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Annex III.

[4] In the past, the NEA/IAEA classification system reported thorium resources in the same way as it reports uranium. Since there is no current major market for thorium, but it is being or could be produced with other, commercially saleable commodities, thorium thus can be reported under UNFC-2009 (see Section III.E in this document).

community as a primary reference document for world uranium supply and demand. IAEA publishes other technical reports, analyses and on-line databases that include this data, such as *"IAEA Analysis of Uranium Supply to 2050"*, *"World Distribution of Uranium Deposits Database (UDEPO)"*, and *"World Thorium Deposits and Resources Database (ThDEPO)"*.

8. Each edition of the "Red Book" contains estimates of uranium resources divided into several categories of assurance of existence and economic attractiveness, along with projections of production capability, installed nuclear capacity and related reactor requirements. Annual statistical data are included on exploration expenditures, uranium production, employment, and levels of uranium stocks. In addition to a global analysis, the report contains detailed reviews of uranium-related developments in Member countries over the two-year reporting period. The "Red Book" is based on official submissions by NEA and IAEA Member States, as well as secretarial (NEA and IAEA) estimates.

9. Uranium resources are broadly classified as either conventional or unconventional. Conventional resources are those that have an established history of production where uranium is a primary product, co-product or an important by-product. Unconventional resources are very low-grade uranium resources from which the uranium is only recoverable as a minor product of developing and processing a mineral ore.

10. Uranium resources are classified according to geological certainty and costs of production (Figure 1). The scheme is used to combine resource estimates from a number of different countries into harmonized global figures.

11. Figure 1 illustrates the inter-relationship between the different resource categories. The horizontal axis expresses the level of assurance about the actual existence of a given tonnage based on varying degrees of geologic knowledge. The vertical axis expresses the economic feasibility of exploitation separated into cost categories.

12. Uranium resource estimates are reported in cost categories. All resource categories are defined in terms of costs of uranium recovered at the ore processing plant. When estimating the cost of production for assigning resources within these cost categories, the various costs have been taken into account. The cost categories, in United States Dollars (USD), currently used in the NEA/IAEA classification as shown in Figure 1[5]. All resource categories are defined in terms of costs of uranium recovered at the ore processing plant. Quantities reported in UNFC-2009 do not have any correspondence with cost categories of the NEA/IAEA classification.

B. Production terminology

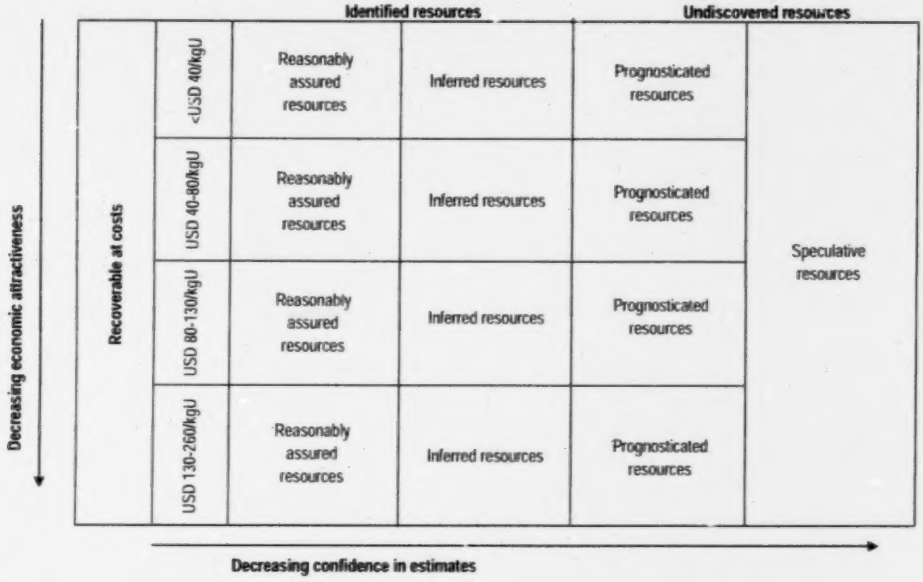
13. The NEA/IAEA "Red Book" uses production terminology for uranium reporting. A production centre, as referred to in this report, is a production unit consisting of one or more ore processing plants, as well as one or more associated mines and uranium resources that are tributary to these facilities. For the purpose of describing production centres, they have been divided into four classes, as follows:

- **Existing** production centres are those that currently exist in operational condition; this category also includes plants that are closed but could be readily brought back into operation;
- **Committed** production centres are those under construction or firmly committed for construction;

[5] Refer to Uranium 2011: Resources, Production and Demand. A Joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, 2012.

- **Planned** production centres are those for which feasibility studies are either completed or under way, but construction commitments have not yet been made. This class also includes plants that are closed and would require substantial expenditures to bring back into operation;
- **Prospective** production centres are those that could be supported by tributary Reasonably Assured Resources and Inferred Resources, but for which construction plans have not yet been made.

Figure 1: Classification scheme for uranium resources as presented in the NEA/IAEA 'Red Book' 2011



III. Direct mapping of categories and sub-categories

A. Application of the G-axis

14. Conventional uranium and thorium resources are sub-divided according to different confidence levels of occurrence, into Identified Resources and Undiscovered Resources. Identified Resources are further sub-divided into Reasonably Assured Resources (RAR) and Inferred Resources (IR). Undiscovered Resources are sub-divided into Prognosticated Resources (PR) and Speculative Resources (SR).

15. Identified resources (RAR and IR) refer to uranium deposits delineated by sufficient direct measurement to conduct pre-feasibility studies, and sometimes feasibility studies. For Reasonably Assured Resources (RAR), high confidence in estimates of grade and tonnage are generally compatible with standards for making mining decisions. Inferred Resources (IR) are not defined with such a high a degree of confidence and generally require further direct measurement prior to making a decision to mine. The Geological Knowledge (G) axis of UNFC-2009 has a direct mapping to the NEA/IAEA Classification Scheme as shown in Figure 2.

Figure 2: Mapping of NEA/IAEA Uranium Resource Categories to UNFC-2009 Classes and Sub-classes.

UNFC Classification					NEA/IAEA Classification	
UNFC Classes and Sub-classes		UNFC Categories				
Class	Sub-Class	E	F	G	Status	IAEA-NEA Categories
Potentially commercial projects	Approved for Development	1	1.2	1,2	Committed	Identified Resources RAR IR*
	Justified for Development	1	1.3	1,2	Planned	
	Development Pending	2	2.1	1,2,3	Prospective	
	Development On Hold	2	2.2	1,2,3		
Non-commercial projects	Development Unclarified	3.2	2.2	1,2,3	Unclarified	Identified Resources RAR IR*
	Development not Viable	3.3	2.3	1,2,3	Not viable	
Exploration projects		3.2	3.1	4		Prognosticated Resources
		3.2	3.2, 3.3	4		Speculative Resources

*Inferred Resources

B. Detailed mapping of the E and F axes

16. Figure 3 shows a mapping of the E-F Sub-category matrix to the NEA/IAEA Classification Scheme with a colour coded–numeric key. Note that colours and numbers are aligned with the CRIRSCO mapping (see the Bridging Document between the CRIRSCO Template and UNFC-2009, ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Annex III) and hence not all numbers are used here.

Figure 3: Mapping of NEA/IAEA Classification to E-F matrix of UNFC-2009

	F1.1	F1.2	F1.3	F2.1	F2.2	F2.3	F3.1	F3.2	F3.3	F4
E1.1		2	3	4						
E1.2		2	3							
E2			4	4	5					
E3.1										
E3.2								9	9	
E3.3										11

NEA/IAEA Classification	NEA/IAEA Classification	NEA/IAEA Production Terminology	UNFC-2009 Sub-classes	Mapping
Identified Resources	Reasonably Assured Resources	Existing	On Production	
		Committed	Approved for Development	2
		Planned	Justified for Development	3
	Reasonably Assured Resources + Inferred Resources	Prospective	Development Pending	4
			Development on Hold	5
		Unclarified	Development Unclarified	
		Not Viable	Development Not Viable	
			Unrecoverable	11
Undiscovered Resources	Prognosticated Resources			
	Speculative Resources			9
			Unrecoverable	11
			Less Common Mappings	

17. Reasonably Assured Resources where sufficiently detailed studies have been completed to demonstrate the feasibility of economic extraction by implementing the defined development project or mining operation corresponds to classification E1F1. The resources can be attributed to "Existing", "Committed" or "Planned" production centres. Optionally, it may be further sub-classified on the F axis into F1.1, F1.2 or F1.3 and on the E axis into E1.1 or E1.2, with appropriate corresponding production centre status as in Figure 2. (Refer to Figure III.3 of the Bridging Document between the CRIRSCO Template and UNFC-2009 (ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Annex III) and the Guidelines on the Use of Project Maturity to Sub-classify Projects using UNFC-2009 (ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Annex V), which provide specific guidance in the differentiation between the project maturity Sub-classes.)

18. Quantities of Identified Resources (Reasonably Assured Resources + Inferred Resources) reported shall correspond to UNFC-2009 requirements of E2 and F2.1 or F2.2 where:

(a) project activities are on-going to justify development in the foreseeable future; or

(b) are on hold and/or where justification as a commercial development may be subject to significant delay. This shall correspond to "Prospective" production centre status.

19. Quantities of Identified Resources shall correspond to UNFC-2009 requirements of E3 and F2.2 or F2.3, where the quantities are technically recoverable, however (a) economically viability cannot yet be determined due to insufficient information (sub-categories E3.2, F2.2) or (b) the resources are not expected to become economically viable in the foreseeable future (sub-categories E3.3, F2.3). The production centre status may be unclarified for these quantities.

20. Mapping of E and F categories to NEA/IAEA production terminology is also shown in Figure 3. The optional UNFC-2009 sub-classes 'On Production', 'Approved for Development' and 'Justified for Development' shall correspond to NEA-IAEA production terminology 'Existing' (E1F1.1), 'Committed' (E1F1.2) and 'Planned' (E1F1.3). NEA/IAEA production terminology 'Prospective' shall correspond to both 'Development Pending' (E2F2.1) and 'Development on Hold' (E2F2.2).

21. Note that the E and F Categories set minimum standards for the UNFC-2009 Classes. For example, a Potentially Commercial Project (Development Pending in Figure 2) must be at least E2 and F2, but it could be also E1F2 or E2F1.

22. UNFC-2009 is a project-based system. Quantities reported in UNFC-2009 can correspond directly to the production centre status of the NEA/IAEA system as in Figure 3, but do not have any correspondence with cost categories. Irrespective of the production centre status, assigning uranium resources to any particular UNFC-2009 Class or Sub-class must satisfy all the minimum requirements of E, F and G Categories. Consequently, resource estimates that reflect (for example) estimated recovery from a committed project must be classified under UNFC-2009 separately from quantities that would not be addressed by that committed project even though they may be associated with the same production centre.

23. UNFC-2009 does not use cost categories as a basis for classification. It is recognized that uranium prices are volatile and any forecasts of future prices are subject to significant uncertainty. In addition, uranium may be extracted on a non-economic basis for other commercial or strategic reasons. Under UNFC-2009, quantities are classified as E1 on the basis that, as at the date of evaluation, there are no known commercial reasons (which include consideration of prices, costs, legal/fiscal framework, environment, social and all

other non-technical factors) that would stop the extraction project from proceeding. The possibility of a project being implemented despite being sub-economic in a strict sense is recognized in the sub-category of E1.2, though it should be noted that there is no obligation to make such a distinction in any reporting (the use of sub-categories is optional).

C. Undiscovered resources

24. Undiscovered Resources (Prognosticated Resources and Speculative Resources) refer to resources that are expected to exist based on geological knowledge of previously discovered deposits, regional geological mapping and other geologic data sources. In UNFC-2009, the quantities estimated for Undiscovered Resources can correspond to E3, F3 and G4. Both Prognosticated and Speculative Resources require significant amounts of exploration before their existence can be confirmed and grades and tonnages of discovered resources can be defined. Additional sub-classification into Prognosticated Resources and Speculative Resources can be aided by Generic Specifications (see Generic specification "Classification of quantities associated with Exploration Projects" (ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Section VI.R)).

25. Prognosticated Resources refer to those expected to exist in known uranium provinces, generally supported by some direct evidence. Quantities estimated shall correspond to UNFC-2009 E3.2 and F3.1. As defined by F3.1, the estimates shall be based on "where site-specific geological studies and exploration activities have identified the potential for an individual deposit with sufficient confidence to warrant drilling or testing that is designed to confirm the existence of that deposit in such form, quality and quantity that the feasibility of extraction can be evaluated."

26. Speculative resources refer to those expected to exist in geological provinces that may host uranium deposits based on favourable regional geologic features for uranium occurrence. Quantities estimated will correspond to UNFC-2009 E3.2 and F3.2 and/or F3.3. As defined by F3.2, estimates are based on where "local geological studies and exploration activities indicate the potential for one or more deposits in a specific part of a geological province, but requires more data acquisition and/or evaluation in order to have sufficient confidence to warrant drilling or testing that is designed to confirm the existence of a deposit in such form, quality and quantity that the feasibility of extraction can be evaluated." As defined by F3.3, studies are "at the earliest stage of exploration activities, where favourable conditions for the potential discovery of deposits in a geological province may be inferred from regional geological studies."

D. Recoverable resources

27. Identified Resources (RAR and IR) estimates are expressed in terms of recoverable tonnes of uranium—quantities of uranium recoverable from mineable ore—as opposed to quantities of uranium contained in mineable ore or quantities in situ, which does not take into account mining and milling losses. While using UNFC-2009, the unrecoverable quantities correspond to E3 and F4. Undiscovered Resources (PR and SR) estimates are expressed in terms of uranium contained in mineable ore; that is., *in-situ* quantities. However, such quantities must still be "potentially recoverable" in order to be designated F3. In some situations, these quantities could be sub-classified based on F4.1, F4.2 and F4.3 (see the Generic Specification "Classification of additional quantities in place" (ECE Energy Series No. 42 (ECE/ENERGY/94) "UNFC-2009 incorporating Specifications for its Application", Part II, Section VI.S).

E. Thorium resources

28. Thorium currently has minor commercial applications. It is considered as a potential fuel for present and future generation nuclear reactors. Presently, thorium is being produced as a by-product of mining and processing other mineral commodities, such as rare earth elements; at some operations thorium minerals are stockpiled for future use. Provided that thorium is stored in a manner in which it remains available for future commercial sale, it may be assigned to E3.2 or E3.3 (and subsequently moved to E2 and E1 once a large scale commercial market emerges for thorium as a nuclear reactor fuel).